NEW METHOD FOR THE INTERMITTENT COLLECTION OF DOPPLER SIGNALS FROM ARTERIAL GRAFTS.

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ABSTRACT -- A portable system for monitoring flow in arterial grafts using a purpose built ultrasonic unit and probe, has been designed and constructed. The system has been used both to monitor blood flow in grafts in the immediate post-operative period, and to investigate changes in flow in well established grafts.

Key words - Ambulatory, Blood flow, Bypass grafts, Instrumentation, Patient monitoring, Ultrasound.

INTRODUCTION

Many arterial grafts fail without warning, some within a short period of time after surgery and others after a longer period of time, for reasons that are not always known. Blood flow and pressure in grafts are labile which makes spot measurements unreliable. To improve our understanding of graft function we decided to monitor blood flow changes over an extended period of time, and also under different physiological condition such as during exercise and with the patient assuming different postures. In this paper we describe the instrumentation involved in collecting and analyzing the data and some preliminary clinical results.

INSTRUMENTATION

It was necessary to design and construct a bi-directional portable Doppler velocimeter and purpose-built probes in order to monitor blood flow in femorodistal bypass grafts in ambulatory patients, since there are none commercially available.

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Design criteria

The Doppler unit must to have the following attributes:

1 - Large bandwidth (70Hz- 12kHz);
2 - Directionality;
3 - A low noise figure;
4 - To be tuneable to probe frequencies between 2 and 4 MHz;
5 - To be compact, have a low power consumption, be battery powered and portable.

To achieve all these requirements, the input matching transformer and the radio frequency preamplifier usually found in such devices were omitted, and the probe matched directly to the demodulators. The high-order bandpass filters which usually attenuate the signals from wall movement and the carrier frequency respectively, were replaced by first-order filters, and the size was further reduced using surface mount technology (Dahnoun et al 1990).

A purpose built timer was also incorporated to conserve both battery life and tape by activating the Doppler unit and the recorder for only 20 seconds at a time, at the same time providing sufficient data to be meaningfully analysed.

Doppler signal recording and analysis

For gathering the Doppler signal, a personal 'stereo' tape recorder was chosen (Sony DC 3 Walkman). This had a good frequency response (60Hz to 14kHz) and an excellent signal to noise ratio (62 dB), with Dolby B-Type noise reduction.

The recorded Doppler signals gathered were analysed using the spectrum-analyser system described by Schlindwein et al (1988). The analysing system produces sonograms in real time showing both forward and reverse flow. The maximum frequency envelope and the intensity-weighted mean frequency and the pulsatility index (PI) are also extracted in real time.

CLINICAL TESTING

The patient measurements were divided into two groups:

(i) continuous measurements;
(ii) periodic measurements.

Method

For both groups of measurements, a purpose built probe was taped over the patient's graft at an appropriate level. The tape recorder's recording level was adjusted so that even for large increases in velocity during activity, the Doppler signals would not saturate the recording circuits. The timer was set either to operate the system continuously, or for approximately 30 seconds every 30 min. At the beginning of the measurements data were taken with the patient at rest and in the supine position. The counter of the recorder was set to zero, so that the time at which the measurements had been taken could be determined retrospectively.

Continuous measurements -- To investigate the effect of exercise and position on flow velocity in arterial grafts, recordings were made whilst the patients were lying down, sitting, standing and exercising on a treadmill at a speed of 2 miles per hour, with an incline of 10 per cent, for 2 min. Patients who were unable to use the treadmill were asked to walk around the laboratory.

The Fig. 1 shows the maximum velocity, the PI, and the intensity-weighted mean velocity (IWMV), plotted against time in a patient at rest and then immediately after exercise. Ten seconds of data were extracted every 15s from the continuous recording to monitor the flow changes. In normal grafts a hyperaemic flow pattern was observed after exercise, and the flow quickly reverted to a normal flow pattern within less than 5 min.

The Fig. 2 shows the flow pattern in an abnormal case with a femorodistal in situ vein graft tunnelled behind the tibia and anastomosed onto the anterior tibial artery. The measurements were taken 3 months after reconstructive surgery was performed. The graph shows a series of recordings from the grafts:
(a) With the patient at rest in a supine position, where the flow appeared to be hyperaemic. (b) After exercise with the patient in a standing position; the flow dropped dramatically from a mean velocity of approximately 7 cm/s to 2 cm/s. (c) Flow after 5 min of rest following exercise was still low. (d) The recording immediately after exercise with the patient in a supine position. The flow in this case returned to normal very quickly. Similar flow patterns were later observed using a duplex scanner.

Periodic measurements -- With this method, we hope to investigate the feasibility of recording the blood velocity in grafts during an extended period of time (24 hours), using the system. With a 60 min tape, and each recording lasting 30s, we have the possibility of recording 120 events. If we wish these 120 events to be spread over 24 hours, the timer has to be set at 32 minutes.

CONCLUSION

A purpose built portable, battery-powered, directional ultrasonic velocimeter unit has been designed, constructed and interfaced to a portable recorder. A number of patients have been monitored with this device and we were able to record Doppler signals for periods of 24 hours or more.

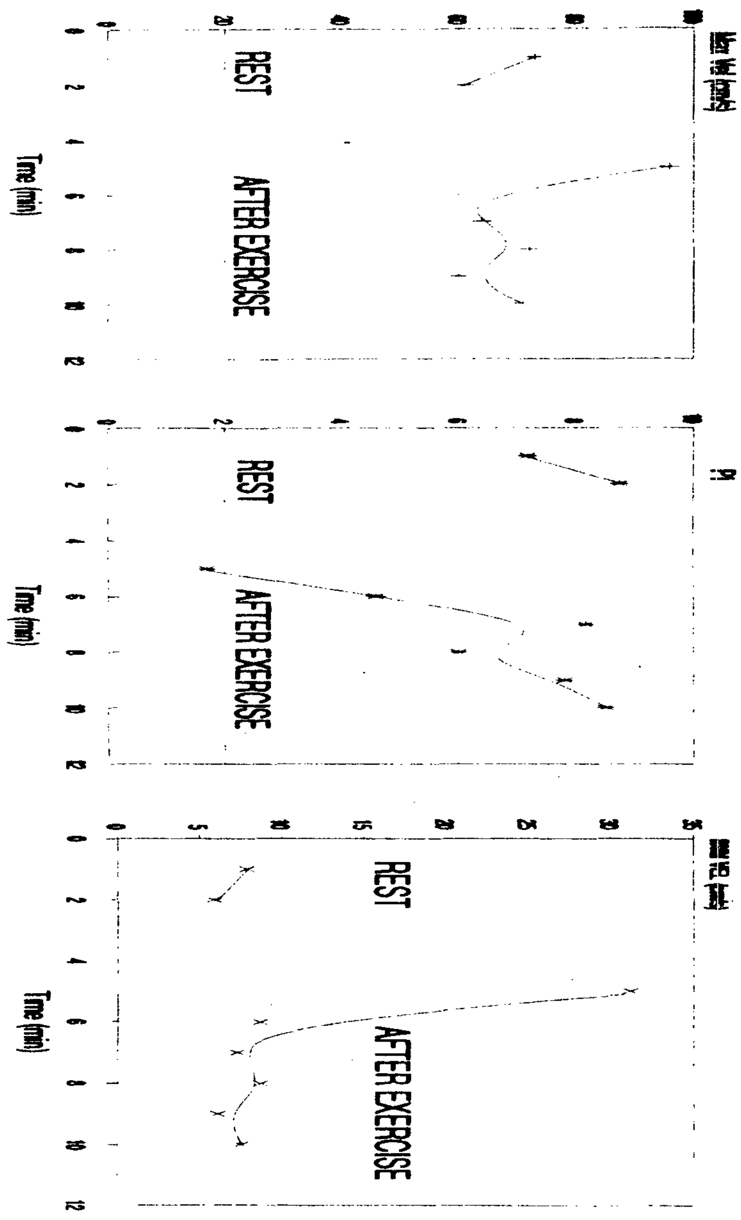

Figura 1. Maximum velocity, PI, and IWM velocity extracted from the Doppler signal obtained with the patient standing at rest, and then following exercise.

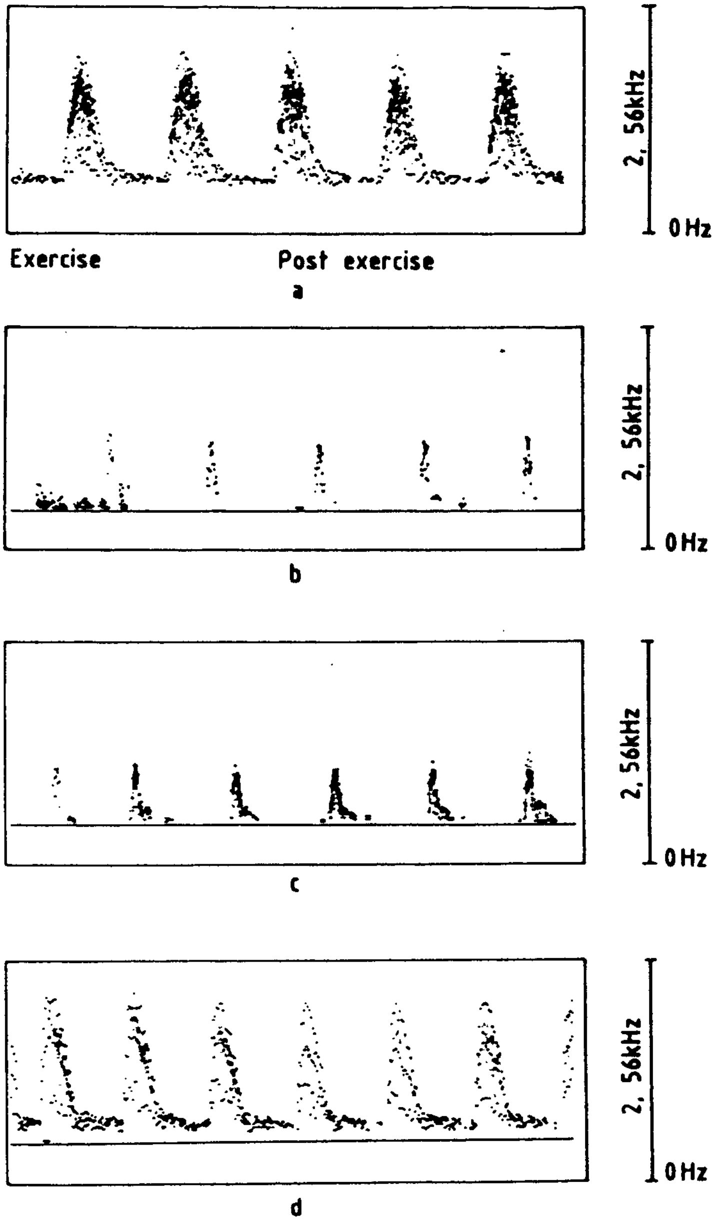

Figura 2 Sonograms recorded from an abnormal case, a) at rest, b) immediately after exercise, c) 5 minutes after exercise and standing still, d) immediately after exercise with the patient in the supine position.

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